THE SOYUZ-6, SOYUZ-7, AND SOYUZ-8 MISSION

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FOREWORD

The present report provides a summary of information released by the Soviet Union during, and immediately after, the flight of the Soyuz-6, -7, and -8 spacecraft.

The report was prepared for the Biotechnology and Human Research Division of the Office of Advanced Research and Technology of NASA by Boris Mandrovsky of the Reference Department of the Library of Congress.

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Introduction

Every time that a major, manned space event takes place in the Soviet Union, Western journalists have a field day. The result is that their reports mix official Soviet announcements with rumors and speculations in such a manner that on the basis of published reports it is virtually impossible to unscramble facts from fancy. The recent Soyuz-6, -7, and -8 mission is no exception.

At the same time, everything published in the USSR, or broadcast by Radio Moscow, constitutes official information. This is the one advantage of dealing with a controlled press. Past experience in monitoring the Soviet press accounts of their manned spaceflights indicates that, while they are given to withholding information, any information released tends to be reliable.

The present report was prepared in order to provide the American space-oriented community with an account which accurately reflects the official information released by the USSR on the Soyuz-6, -7, and -8 mission.

The Mission in Brief

As is now well-known, in mid-October of 1969, the Soviet Union placed three spacecraft of the Soyuz type in orbit on successive days. Each spacecraft remained in orbit for five days (80 orbits). In the course of their mission, the spacecraft performed a number of maneuvers (most of them manually) and carried out a large program of scientific and technical observations and experiments [26, 27, 29]. The three spacecraft landed successfully, on successive days, in a designated area, between 180 km north and 145 km north-west of the city of Karaganda. The precision of the landings was such that in all cases the rescue helicopters were in the area of landing by the time the spacecraft touched the ground [13, 18, 21].

It was reported that all systems and equipment on the three spacecraft were functioning properly during the entire course of the flights. It was also reported that cabin parameters stayed within the assigned limits and that all cosmonauts felt well.

Orbit Parameters and Flight Duration

The Soyuz-6 was launched at 14:10 hr (all time references in this report are given in Moscow time) on 11 October 1969 from the Baykonur Cosmodrome with spacecraft commander Georgiy Stepanovich SHONIN and flight engineer Valeriy Nikolayevich KUBASOV on board [1]. The Soyuz-7 was launched at 13:45 hr on 12 October 1969 with spacecraft commander Anatoliy Vasil'yevich FILIPCHENKO, flight engineer Vladislav Nikolayevich VOLKOV, and research engineer Viktor Vasil'yevich GORBATKO on board [4]. The Soyuz-8 was launched at 13:29 hr on 13 October 1969 with spacecraft commander Vladimir Aleksandrovich SHATALOV and flight engineer Aleksey Stanislavovich YELISEYEV on board. The Soyuz-8 was designated the flagship of the three-spacecraft mission and Shatalov was designated as the commander of the group flight [5, 6, 21].

Initial Orbital Parameters

	Soyuz-6	Soyuz-7	Soyuz-8
Apogee	223 km	226 km	223 km
Perigee	186 km	207 km	205 km
Angle of inclination	51.7°	51.7°	51.7°
Period of revolution	88.36 min	88.6 min	88.6 min

[1, 4, 6]

In the course of the mission the three spacecraft executed a number of maneuvers and synchronized their flight so that by 15 October the following orbital parameters were given for the group as a whole: apogee – 225 km, perigee – 200 km, angle of inclination – 51.7°, period of revolution – 88.6 min [9].

Flight Duration and Landing

	Soyuz-6	Soyuz-7	Soyuz-8
Duration of flight	118 hr 42 min	118 hr 41 min	118 hr 41 min
Touchdown time	16 Oct, 12:52 hr	17 Oct, 12:26 hr	18 Oct, 12:10
Place of landing	180 km NW of Karaganda	155 km NW of Karaganda	145 km N of Karaganda

[13, 18, 21]

In all three cases the landings were so precise that the search and rescue helicopters were on hand at the time of the landing.

Group Control

Speaking of the Soyuz-6, -7, and -8 mission, Academician M. V. Keldysh (the President of the Academy of Sciences of the USSR) stated that one of the major objectives of the mission was to create a complex, maneuverable, orbital system in which spacecraft pilots could interact with a large complex of automatic equipment [26]. Shatalov (the commander of the group flight), stated that the most demanding part of the mission lay in carrying out mutual maneuvers and working out methods of combined actions of the crews of the three spacecraft with the Ground Control Center [27]. Shonin (the commander of Soyuz-6) added that the most difficult stages of the flight were those which involved mutual manual maneuvering and autonomous navigational measurements [29].

During the first day that all three Soyuz spacecraft were in orbit, they worked out methods of controlling the flight of the three spacecraft simultaneously, and checked communications with the Ground Control Center, the other tracking stations, and the tracking ships on the high seas. Computers at the Control Center confirmed the efficiency of the group control methods which were used [6].

The Deputy Director of the Operations Group at the Ground Control Center (who is credited with developing the guidance system for the Soyuz spacecraft) stated that two types of maneuvers were used during the Soyuz-6, -7, and -8 flight. The first type was automatic, carried out by the Ground Control Center. In this case all of the data concerning the orbital parameters of the spacecraft were obtained by ground facilities and the Control Center then issued orders supplying all of the necessary data on the magnitude and direction of the correcting thrusts which were needed to perform any given maneuver. In this type of operation the cosmonauts often did not even see the other spacecraft [24, 27].

The second type of maneuver was carried out manually on the basis of autonomous navigation. The Control Center did not intrude or participate in this type of maneuver. The cosmonauts made their own decisions as to what to do in order to carry out maneuvers using only on-board facilities and inter-spacecraft communications, without any assistance from the ground facilities [24, 27].

Soyuz Controls and Equipment

TASS reported that during the time that the three spacecraft were in flight together, they spent much time checking both the automatic and the manual systems of control [7]. The first step of this phase of the mission consisted in checking out the on-board control systems and navigational equipment of the updated design of the Soyuz spacecraft [27].

Feoktistov (the cosmonaut scientist who made the trip on the Voskhod-1 and who is believed to have had a hand in the design of the Soyuz spacecraft) pointed out that Soyuz controls were designed with the idea of liberating crews from the elementary functions of control which could be taken over by automatic equipment. In contrast with modern aircraft which have dozens of switches, each of which is intended to perform a single function, on the Soyuz, maneuvers can be carried out by pressing a single button which activates a programmed operational sequence issuing dozens of commands. This greatly simplifies the maneuvering of spacecraft when time is short. However, each of the individual commands can also be initiated by the cosmonauts manually [8, 30].

The indicators on the Soyuz control panel show the position of the spacecraft above the surface of the Earth, the distance and rate of approach to other spacecraft, the parameters of the cabin atmosphere and the life support systems, the rate of charge (or discharge) of the chemical storage batteries, the network voltage, and the parameters of the pneumohydraulic systems for controlling the various engines and thrusters [30].

The controls are located in two groups: one on each side of the indicator panel. The push-buttons make it possible to initiate operational systems of the spacecraft and to monitor procedures on the basis of signal lights on the control panel. Any two members of the spacecraft can control all of the systems, or the man in the middle (the commander) can control all of them by himself. The left-hand group controls the systems of communication, descent, and life support; while the right-hand group controls all of the remaining systems of the spacecraft [30].

The updated design of the Soyuz spacecraft used during the present mission carried four different types of engines. The first of these, designated by Filipchenko as the "approach-correction engine" is the main engine used for carrying out maneuvers in orbit, and also serves as the retro-fire engine during reentry. This engine can be activated manually by a simple on-and-off push-button, or it can be activated automatically from the ground. The second type consists of "low thrust engines" used for attitude control. They are actuated by means of a handle and can turn the spacecraft about any of its axes. Engines of the third type (translation thrusters) are also intended for turning the spacecraft in relation to its center of mass. These are controlled by means of a separate handle. They were also used for small approach displacement of the spacecraft during mutual maneuvering. The fourth type consists of engines used for controlled descent and these, in contrast with the others, are located immediately on the descent module. These are used for carrying out programmed turns of the ship before reentry into the denser layers of the atmosphere, and also for banking and stabilization in respect to the other axes during flight within the atmosphere [30].

Filipchenko stated that the Soyuz controls handle very well. The volume of incoming information is adequate making it possible to evaluate and control a number of the spacecraft systems effectively. Information is presented in a manner which does not cause fatigue. He added that the spacecraft is exceptionally responsive to controls and reacts faultlessly to the movements of the control handles [30].

Autonomous Navigation

Navigational experiments carried out on the Soyuz-6, -7, and -8 consisted of two parts: the first of these consisted of testing the various navigational instruments and the second consisted of working out methods of autonomous navigation [32]. The Soyuz spacecraft were equipped with optical sighting devices, shadow indicators, ionic sensors, computers, and other instruments for autonomous navigation [24, 30, 32]. In addition, a new type of sextant was carried on Soyuz-7 while astro-orientators and automatic stellar sensors were carried on Soyuz-6 [8, 30, 32].

Optical sighting devices (which apparently were carried on all three spacecraft) were tested by location and recognition of terrestrial navigation points (landmark trackers) [32]. Other instruments, such as the sextant and the astro-orientator, were checked by measuring known angular distances between stars [32].

Volkov (the flight engineer of Soyuz-7) stated that there were two basic methods of autonomous navigation used during the Soyuz-6, -7, and -8 flight. The first of these was based on terrestrial orientation points, while the second was based on the measurements of position of certain stars in relation to the horizon of the Earth.

The shadow indicator was located on the outside of the window and was used for a preliminary search of the Sun followed by a precise orientation [30]. The optical sighting device was intended primarily for use on the illuminated side of the Earth [30]; however, it appears that the Soviets also tested the optical sighting device in the twilight zone and in the shadow of the Earth [7]. For the purpose of sighting navigational orientation points on the Earth, the optical sighting device was positioned perpendicularly to the longitudinal axis of the spacecraft. However, it was a dual purpose device and during approach maneuvers it was used in parallel to the longitudinal axis of the spacecraft [30].

The stellar method of navigation was used on Soyuz-7 with the aid of the new sextant. Volkov pointed out that first and second magnitude stars can be clearly seen even on the daylight side of the Earth [8, 32]. On board the Soyuz-6 Shonin and Kubasov perfected a technique of visual astro-orientation on fourth and fifth magnitude stars, using astro-orientators and automatic stellar sensors [6, 32]. The actual use of these two devices is not described, but it appears that the astro-orientator was used for pinpointing a star while the automatic stellar sensors tracked it as the spacecraft continued to move. Using this system of stellar orientation it was possible to locate the position of the spacecraft without using any ground facilities or terrestrial identification points [6].

The velocity vector of the spacecraft was determined by means of ionic sensors [7, 30]. These were used together with on-board computers for determining the relative motion of the spacecraft [34].

Mutual maneuvers

In the course of the Soyuz-6, -7, and -8 mission more than 30 major maneuvers were carried out; most of these were carried out manually on the basis of autonomous navigation [27]. These maneuvers included a number of approaches between spacecraft [9, 15]. Soyuz-7 and Soyuz-8 had automatic approach systems on board which were tied into manual control. These systems had been previously tested on Kosmos-186 and -188 and also on Soyuz-4 and -5 [27].

During the present mission the Soyuz-6 and Soyuz-8 repeatedly approached the passive Soyuz-7 [9, 15, 24]. Every time that such a maneuver was carried out autonomously it was necessary to determine orbit parameters, to calculate the necessary orientation of the spacecraft and the magnitude of the required correctional thrusts [27]. The evaluation of parameters of motion was carried out on the basis of algorithms using on-board computers. The results of these calculations coincided well with the data of trajectory measurements at the Ground Control Center [32].

This procedure was followed until the spacecraft were within sight of each other. After that, maneuvers were carried out on the basis of relative motion (of the two spacecraft) whose parameters had to be determined with the aid of on-board computers by the flight engineers of the spacecraft. These included: distance, approach velocity, and the angular velocity of the line of sight. Shatalov reported that the angular velocity of the spacecraft created something of a problem since it had to be cancelled out manually by the use of "approach-correction" engine [27].

The measurements obtained by the flight engineers of the two approaching craft were then compared [27]. The simultaneous solution of navigational measurements of the two spacecraft made it possible to use a single correcting thrust for accomplishing the approach from several tens of kilometers down to 500 meters [32]. The flight engineer of the active spacecraft read out instructions concerning the necessary orientation of the spacecraft and the duration of the burn to the pilot who then carried out the necessary directions [37]. Coordinated work on the part of the crews kept fuel consumption of the correctional and the low-power thrusters to a minimum [27].

During this type of approach, the passive Soyuz-7 tracked the active spacecraft (Soyuz-6 or Soyuz-8) continuously [27]. While Soyuz-7 and Soyuz-8 were carrying out the approach maneuver, both spacecraft were also observed from Soyuz-6 [9].

Communications

Most of the communications between the spacecraft and between the spacecraft and the Ground Control Center were operational. However, towards the end of the flight an experimental communication network was set up between Soyuz-8 and the Ground Control Center via the new Soviet communication satellite Molniya-1. According to Yeliseyev, the communication from the Ground Control Center was first transmitted to the "Orbit" system, then via Molniya-1, or via the ship "Kosmonavt Vladimir Komarov" to the spacecraft. This provided a stable two-channel system of radio communication. The use of such a system makes it possible to extend substantially the communication contact time between the spacecraft and the Ground Control Center. This is especially important where a large part of the flight takes place beyond the zone of radio visibility of the territory of the Soviet Union [33].

While the spacecraft were within visual distance of each other, they also investigated the possibility of communicating with each other by means of light signals [9]. More specifically, they investigated the volume and amount of information that it was possible to transmit using light signals and visual-optical methods. The Soviets consider that these data are important for the solution of a series of problems in perfecting autonomous operations during the assembly of a long-term orbital laboratory [7].

Results of maneuvers

The Deputy Director of the Operations Group stated that during maneuvering of these three Soyuz spacecraft situations arose which were not foreseen by either the cosmonauts or the Ground Control Center. He added that the cosmonauts were able to solve these problems successfully and that as a result of this much valuable data on mutual maneuvering was obtained [24].

As a result of these maneuvers data were obtained on the most effective method of approach using on-board data for determination of dynamics of such mutual approaches. Valuable data were also obtained on fuel consumption during various maneuvers and during maintenance of attitude control [27]. Shatalov stated that manual control turned out to be more economical in terms of fuel than was initially assumed and that consequently it was possible to carry out more maneuvers than the program called for originally [34]. In addition, methodology was worked out for crew interaction during each maneuver, and data were obtained on the most rational distribution of functions between men and automatic devices [27].

It was possible to carry out all of these maneuvers successfully because communication and coordination between the spacecraft crews, the Ground Control Center, and the ground stations and ships was excellent [27].

The updated version of the Soyuz used in the present mission successfully demonstrated its capability for autonomous navigation [24]. Shonin summarized the situation by stating that Soyuz is a most versatile and promising spacecraft capable of independent navigation [52]. Cosmonaut Beregovoy (who had flown in the Soyuz-3) stated: "Sooner or later, without renouncing aid from the ground, we shall achieve autonomy in spaceflight, and the on-board equipment will do much of the job that is currently done by the ground facilities. Autonomous navigation is a vital need." [47]. The use of autonomous navigation and manual control are considered essential for the development of a pilotable space system which, in turn, is an absolute necessity for the construction and assembly of large orbital stations [9, 27].

Scientific Investigation Program

In addition to the operational program of autonomous navigation and manual maneuvering, the Soyuz-6, -7, and -8 mission had a heavy program of scientific observations and investigations [29]. This program included geological and geographic photography and observations, photography and observation of the spectral brightness of the surface of the Earth, meteorological observations, and photography and measurement of horizons for determination of the structure of the atmosphere [33]. Other studies included photography of celestial bodies and studies of micrometeor erosion, luminescent particles, and cosmic and solar radiation [6, 7, 9].

Geological and geographic investigations included the simultaneous photography of characteristic areas of the Earth's surface from three points in space [6, 27]. At the same time aerial photography of these same regions was carried out by aircraft flying at various altitudes. A comparison of these photographs with data from geological, geobotanical, and other expedition studies will make it possible to develop a methodology for utilizing photographs obtained from space for solving various geological and geographic problems related to geological map making and to the study of the natural resources of the Earth [33]. These geographic and geological investigations have a direct relation to problems of national economy [10].

Investigations of the spectral brightness of the surface of the Earth involved photography on both the twilight and daylight sides of the Earth, and measurement of the amount of illumination reflected from the surface of the Earth [6, 7, 27]. More specifically, the investigation dealt with contrast in spectral brightness, in the visible part of the spectrum, of various surfaces of the Earth. The study of various surfaces (such as: snow, desert, sea, forests, plains, etc.) will make it possible to classify them on the basis of spectral brightness. This will make it possible to work out a methodology of recognition of various types of surface on the basis of photographs, television images, and data of spectral measurements [33]. This, in turn, will facilitate keeping track of snow cover in remote mountain areas, the preparation of geobotanical maps, and performance of other services useful to the national economy [9, 34].

Meteorological investigations included photography and observation of the processes of formation, development, and movement of various cloud patterns (including typhoons and cyclones) [6, 7, 9, 27, 33].

The spectral and photometric studies included the photography of the day-time and twilight horizons, the study of polarization of sunlight by the upper layers of the atmosphere, and of processes in the upper layers of the ionosphere [6, 7, 9]. Photography of the horizon of the Earth was made in various areas of the visible spectrum. The brightness characteristics of the horizon made it possible to obtain data concerning the aerosol structure of the atmosphere. The statistical processing of results of a large number of photographs will make it possible to identify precisely the altitude relationship of the brightness of the profile to the true horizon of the Earth, and thus to reveal the optical nonhomogeneity of the terrestrial atmosphere [33].

Minor physical investigations included photography of the stellar sky and of celestial bodies (including photography against the background of the horizon of the Earth), the determination of the actual brightness of the stars, observations of luminescent particles which accompanied the spacecraft and the dynamics of their movement, observations of the effect of micrometeorite erosion on the condition of the windows and optical systems of the spacecraft, and the study of solar and cosmic radiation with special equipment [6, 7, 9, 27].

The Welding Experiment

The Soyuz-6 carried special on-board equipment for performing a welding experiment [1, 10]. Welding in space will be needed for the building of large orbital stations as well as for repair of vehicles which have been in space for long periods of time [10, 15, 16, 28]. It is also suggested that weightlessness and the deep vacuum of space would create ideal conditions for industrial production of super pure metals [10]. The specific purpose of the welding experiment was to determine the peculiarities of welding under conditions of space and to investigate methods of welding that would be most useful for the construction of large orbital stations [16, 28].

These welding experiments were designed by the Electric Welding Institute im. Ye. O. Paton of the Ukranian Academy of Sciences [28]. Preparations for the welding experiment began several years ago. Electron-beam welding, low-pressure compressed arc welding, and welding by consumable electrodes are simple, reliable and can be easily automated. However, these methods produce large amounts of steam and gases. Consequently, it was necessary to find out how they would react under conditions of vacuum and weightlessness and to design special equipment which would be suitable for working in space [16].

Since it is difficult, if not impossible, to create all of the conditions of space on earth, preliminary investigations had to be carried out in stages, each of which simulated only part of the factors found in space [16]. Then, under conditions of ordinary vacuum chambers, principles of construction of highly reliable, compact welding devices were developed for each of the types of welding to be tested. The welding methods tested were those where surface tension alone was required to hold the molten metal within the welding baths. The next step was to design small size welding devices and special vacuum chambers and pumps which could be installed on board the "flying laboratory" in which short-term weightlessness could be created. The samples tested in the vacuum chambers on the "flying laboratory" were analyzed. This analysis indicated that substantial changes took place in the microstructure of the welding seams. It was also found that the welds were somewhat stronger. However, in some cases, it was possible to observe a porosity in the seams [16].

It was also found that using a consumable electrode in weightlessness required special precautions to assure reliable transport of metal from the electrode to the bath. Pulsed current had to be used since, in weightlessness, the drops of the electrode metal reached such sizes that the process of welding was interrupted [16].

The final stage of the preliminary experiments simulated spacecraft conditions. The chamber was equipped with a high-speed pump to simulate space conditions by rapidly removing gases from the welding zone. It turned out that the usual methods of igniting arcs by means of high frequency discharge could not be used under these conditions. Consequently, it became necessary to develop a special method of igniting and to create special devices for welding by low-pressure compressed arc [16].

As a result of these preliminary experiments, it was possible to create an experimental, automatic, 50-kg welding device which was named "Vulcan". This device was used on the Soyuz-6 for studying the welding process by three different methods: compressed arc welding (using low tempreature plasma), electron beam welding, and welding by the use of consumable electrodes. It is also possible to use the "Vulcan" to imitate the work of a hand-held welding instrument [28].

The "Vulcan", a completely automated device, consists of two major units. The first of these consists of various welding devices and a turn-table with samples of metals to be welded. The second consists of an electric power pack, a protective shield which covers the welding unit, and a remote control console [16, 28]. Kubasov, who performed the experiment on Soyuz-6, explained that the "Vulcan" was a strictly experimental device and not an operational tool. However, he admitted that some elements of the "Vulcan" device could be used to perform repair work in case of emergency [34].

The operational sequence of using the "Vulcan" device in space was carefully worked out and rehearsed in the "flying laboratory". Kubasov participated in these experiments and was thoroughly familiar with the sequence of operations to be performed during the welding experiment in spaceflight [28]. The experimental sequence began when Shonin (the commander of Soyuz-6) sealed off the hatch between the orbital module where the welding device was located, and the command module where Shonin, Kubasov, and the control console of the welding device were located [28]. After the hatch was sealed between the two modules, the orbital module was depressurized until space conditions prevailed in it. Then Kubasov initiated automatic welding using the low-pressure compressed arc method. After this, he tested the electron beam method of welding and finally the consumable electrode type of welding [16, 28].

These operations included the welding of thin sheets of construction materials (stainless steel and titanium). After this, the cutting of stainless steel, of titanium, and of aluminum was carried out by means of the "Vulcan" device. The experiment also included the welding of non-metallic materials and observation of the behavior of drops of liquid metal and of the welding bath in weightlessness [26]. All of these processes were carefully monitored by Kubasov from the control panels by means of TV. The "Vulcan" device could also be controlled from ground stations by means of telemetry [16, 28].

After the completion of the experiment (which was performed during the 77th orbit of Soyuz-6), the orbital module was repressurized, the hatch between the two modules was opened and Kubasov then carried out a hand-held welding operation using part of the "Vulcan" device while Shonin photographed this performance [12, 16, 28]. This experiment was conducted to determine the most efficient procedures for hand-welding in weightlessness. The movie will make it possible to check on procedures and to make recommendations for improvement in the use of welding equipment by cosmonauts [28].

Although the data from the experiment have not yet been evaluated, it is already evident that welding is possible under spaceflight conditions. The "Vulcan" device operated reliably under these conditions and it is assumed that in the future it will be possible to utilize welding for repair work and for construction of orbital stations. It is also possible that welding will be used in future space operations in order to obtain super pure metals [16, 28, 34].

Medical Monitoring and Biomedical Investigations

Throughout the flight TASS reported that all cosmonauts felt well [6, 7, 17]. These statements were supported by the head of the biomedical team at the Ground Control Center, who stated that the condition of the cosmonauts during the entire flight did not cause any alarm among the physicians, that all cosmonauts felt well during all stages of the flight, and that all had retained their full work capacity [15, 25]. The Chief of the Biomedical Monitoring Group at the Control Center explained that the physiological condition of the cosmonauts was monitored on the basis of usual biotelemetry parameters (pulse rate, respiration rate, arterial pressure, EKG, and seismocardiography). He added that additional valuable information was provided by observing them via TV and analyzing the physical characteristics of their speech [4, 15].

The TASS reports and other Soviet articles also made repeated references to a program of biomedical investigations conducted on the three Soyuz spacecraft. It appears that the main thrust of these investigations was to determine the ability of humans to function effectively when exposed to prolonged or extended weightlessness. The Director of the Biomedical Training of the cosmonauts stated that the biomedical investigations on this flight were not simply a continuation of experiments performed on previous flights. He went on to say that it is already established that man can exist in orbit for short periods of time, but that it is not yet known whether man can exist on an extended flight in a "star ship" [44]. Anatoliy Karitskiy, the scientific commentator of TASS, stated that the current program of biomedical investigations is part of a "vast program of studying questions connected with man's presence in conditions of space." He explained that the main stress of these investigations was the study of physiological reactions to weightlessness and man's ability to retain his work capacity in space [38]. B. B. Yegorov (the cosmonaut physician who flew on Voskhod-1) explained that the crew of Soyuz-7 carried out a number of interesting experiments to study human adaptation to weightlessness. He added that previous Soviet spaceflights showed that human physiological functions did not fully adapt to weightlessness [40].

Academician Keldysh stated this problem even more acutely when he identified weightlessness as "the most significant problem which is standing in the way of creation of a permanent orbital station." He added that it is necessary to clarify a whole series of questions related to the prolonged stay of man in orbit, and that Soviet biomedical specialists do not agree on the question of whether man can remain for an extended period of time (months or years) in orbit under conditions of weightlessness without serious consequences. He concluded that if it turns out that weightlessness will really have unfavôrable effects on humans, it will be necessary to create long-term stations with artificial gravity [35].

Gorbatko (the research engineer of Soyuz-7 whose duties included careful monitoring of the operation of the life support systems and biomedical experiments) stated that in the course of the flight they had carried out a number of biomedical experiments whose purpose was to study the adaptability of human reactions to spaceflight factors, and especially to weightlessness. He explained that they monitored respiration frequency and energy expenditures while carrying out various operations under weightless conditions and studied the effect of calibrated (i. e. measured) physical loading on the magnitude of arterial pressure and pulse frequency [31].

The Chief of the Biomedical Monitoring Group at the Control Center stated that all cosmonauts adapted quickly to weightlessness and other spaceflight conditions, but that the crew of the Soyuz-8 adapted more quickly than the others, possibly because this is their second time in space [15]. One of the specialists responsible for biomedical safety of the flight stated that shortly after return to Earth all seven of the cosmonauts readapted to normal gravity very quickly [25].

The biomedical parameters that were measured in the course of these investigations are not explicitly detailed. However, it is known that cardiac activity was monitored on the basis of EKG and seismocardiography. In addition, the pulse rate and arterial pressure were measured [4, 15, 31]. Respiration was measured by pneumography [4, 9, 15]. The pulse and respiration rates of the individual cosmonauts were not reported throughout the flight. However, towards the end of the flight, it was stated that the pulse rate of the cosmonauts varied between 60 and 76/min and that the respiration varied between 18 and 20/min [12].

Biomedical investigations also included functional and psycho-physiological tests to determine the level of work capacity [7]. These tests also included studies of the vestibular organ, the visual analysor, and various motor reactions (including the visual work capacity) of human operators [9, 31]. Psycho-physiological tests made it possible to obtain valuable data on such functions as memory, attention, and the shift of attention [31]. Studies were also carried out on energy expenditures used to perform various operations under weightless conditions [31].

Biomedical data are being processed and presumably will be published at a later date. The only positive nugget of information of biomedical results is a statement by Shatalov who pointed out that in five days in space he lost only 2.3 kg as compared to 4 kg that he lost in the three days of his previous flight on Soyuz-4 [34].

Life Support Systems and Living Conditions

One of the published Soviet reports stated that the complexity and intensity of the Soyuz-6, -7, and -8 mission made it necessary to develop "new and more powerful systems of life support, and first of all, systems of regeneration and conditioning of air" [20]. This statement should be taken with a grain of salt. The term "new" probably refers to updated design of their standard life support systems. The Soviet term "regeneration" really refers to revitalization. There was no real evidence published that the systems used in the present flight are different in principle from those used on previous flights. Academician Keldysh, in speaking of problems that will have to be solved before permanent space stations can be constructed in orbit, stated that life support systems which can assure long term sojourn of man in space have to be developed [35].

It was reported that during the flight of the Soyuz-6, -7, and -8, the life support systems worked faultlessly [25], and that these on-board systems could even compensate for small leaks [34].

Living conditions in the spacecraft were described as being very close to comfortable and the spacecraft cabin parameters were reported throughout the flight as being normal, or within assigned limits [6, 9, 17, 23]. Normal terrestrial atmospheres prevailed in the cabin and the cosmonauts worked in a shirt-sleeve environment [1]. Space suits were not worn, and were not even carried on any of the spacecraft during this flight [34, 36, 37].

Gorbatko, in summarizing the flight, stated that throughout the flight cabin pressure ranged from 750 to 800 mm Hg, the pO_2 ranged from 160 to 220 mm Hg, the pCO_2 ranged from 1 to 10 mm Hg, relative humidity ranged from 40 to 70 %, and temperature was held around 20° C [31]. Cabin parameters were not frequently reported by TASS during the course of the flight. When reported, they usually fell within the limits designated by Gorbatko. However, on one occasion (16:00 hr, 14 Oct 69) TASS reported a cabin pressure of 820 mm Hg and a temperature of 24° C [7]. The radiation level in the space cabin was low, many times smaller than the permissible dose [25].

The two cabins of the Soyuz spacecraft have been described as roomy and comfortable. The sea-level atmosphere provided a shirt-sleeve environment which enabled the cosmonauts to be comfortable in what was called "athletic clothing" (gym or sweat suits) [14]. The orbital compartment of the Soyuz spacecraft is intended for rest, recreation and sleep, as well as for scientific research. This compartment contains space for slinging sleeping bags. However, the cosmonauts preferred to sleep on the more usual couch. In order to keep from floating about, they used restraint straps [31]. Sleep during the flight was described as being deep and quiet [12].

The cosmonauts ate four meals per day. The daily caloric intake amounted to 2600 Kcal [31]. Spacefood, as packaged, contains somewhat less moisture than normal food, i. e. it is more concentrated. It is not difficult to adjust to it. It contains everything necessary for nutrition, including vitamins, and at the same time it is sufficiently diversified [19]. Most of the food items were natural products such as meats (tongue in jelly, chicken, roast beef), liquid products (coffee, cocoa), sweets (candy, candied fruit), various types of bread, and also various fruit juices [31].

A typical breakfast consisted of apricots, bread, chocolate, and juice of black currents. A typical dinner (mid-day meal) included dried (or smoked) fish, pate, chicken, bread, and prunes. An alternate menu consisted of meat puree, veal, bread, and cookies [6]. Still another variant consisted of liver pate, chicken, bread, and fruit candy [9]. Milk, coffee, cocoa, and various fruit juices were available by way of liquids.

Long-Range Goals and Future Plans

The Chief Designer stated the Soviet attitude about the present Soyuz mission as follows: "As far as we are concerned, this is an operational mission. This is not an experimental or test flight, but rather a tool for scientific investigation and for development of methods of orientation and space navigation" [10].

The checking of the updated and improved design and equipment of the Soyuz spacecraft is regarded only as a means to an end [1]. The Soyuz is regarded as a multi-purpose tool intended for a wide program of research serving the needs of science and the national economy [31]. Shatalov pointed out that the possibilities of Soyuz spacecraft in carrying out maneuvers, have by no means been exhausted during the current mission. He felt that Soyuz spacecraft have tremendous exploitable engineering qualities and that they can be used as space laboratories for the conduct of the most varied experiments [27].

The Soviet reports stressed, again and again, that the development of control of a complex pilotable system which loomed so large in the present mission, was not an end in itself but a step towards the creation of large, permanent orbital stations [1, 5, 15, 26, 35, 47]. Cosmonaut Beregovoy stressed that autonomous navigation, without aid from the ground, is a vital need which will be very useful for the construction of large orbital stations [47]. The Chief Designer stated that the data received as a result of the complex group flight are essential for the assembly of large orbital stations [15]. Scientist-cosmonaut Feoktistov stated that the purpose of the intensive maneuvering during the present flight was to accumulate experience that will be useful in the creation of orbital stations which will be capable of functioning in space for long periods of time. He stated that the assembly of orbital stations is unthinkable without autonomous navigation and manual maneuvering on the part of the cosmonauts [45]. Academician Keldysh announced that mutual maneuvering and control of a group of spacecraft in flight was perhaps the most important aspect of the present mission. since this experience will be most useful for the creation of habitable orbital complexes in the near future [26, 35].

Biomedical experiments formed a substantial part of the program of the current mission. The significance of these biomedical experiments was pointed out by Keldysh when he stated that the most significant problem standing in the way of creation of a permanent station in orbit is the clarification of whether or not man can stand weightlessness for extended periods of time [35]. This statement may also explain why each of the spacecraft stayed in flight for exactly the same amount of time (118 hr 41 min) [34]. The Director of Biomedical Training of the cosmonauts pointed out that the biomedical experiments of the current mission were performed in order to determine whether or not man can exist and function effectively as an operator during extended spaceflights [44].

According to a group of Soviet scientists, the objective of the Soyuz-6, -7, and -8 mission was to do everything possible to bring closer that time when a permanent orbital station could become operational [20]. Keldysh pointed out that the Soviet space program is currently examining the problems related to the creation of long term orbital stations [26]. One of the designers of the welding experiment characterized the building of orbital stations as the central problem in cosmonautics today [48].

Brezhnev stated that the Soviet Union has an extensive space program calculated for many years. He added that Soviet science has decided that the creation of long-term orbital stations with replaceable crews is the main route into space for man [53]. The Central Committee of the Communist Party, the Presidium of the Supreme Soviet of the USSR, and the Council of Ministers of the USSR issued a joint statement summarizing the achievements of the Soyuz-6, -7, and -8 flight as follows: "Seven Soviet cosmonauts completed a broad program of work in solving important and practical problems necessary for the perfecting of techniques of piloting spacecraft and the creation of orbital stations of scientific and national economy significance" [22].

The fact that the Soyuz mission and the entire Soviet space program have significance for the national economy was consistently stressed in the Soviet press during the current mission. Academician Keldysh, the Chief Designer, and Cosmonaut Yeliseyev detailed some of the possible uses that the space program may have for the national economy of the USSR. These included service to meteorology, study of the dynamics of the snow cover, forestry surveys (including fire watching), photography which would reveal the ripening of grain, the spread of plant diseases, the migration of locusts, help in the preparation of geobotanical, geological, and geodetic maps, the location of mineral resources, the plotting of fish migrations, and other oceanographic studies [10, 26, 34, 38]. This stress on the fact that the space program has practical applications for terrestrial purposes appears to indicate that the Soviet space program has to be sold to the people in order to obtain popular support.

Keldysh, in response to questions from journalists, explained that the USSR has a broad program for investigating the planets and for the creation of an orbital station. He explained that for the time being, exploration of the moon and the planets will be performed with automatic equipment and added that the USSR does not plan to send man to the moon in the immediate future. The current major goal of the Soviet manned spaceflight program is the creation of a large permanent station or platform in terrestrial orbit. He explained that the mutual maneuvers, the group control of three spacecraft, and the success of the welding experiment have brought closer the day when the Soviet Union expects to have a station in orbit. He added that he expected such a station to be in orbit in less than ten years, and probably less than five [35].

COMMENTS

Despite the hints and comments of Western journalists, there is no evidence in the extensive coverage given the Soyuz-6, -7, and -8 mission by the Soviet press that the mission was anything but an unqualified success. Many Western journalists anticipated spectacular docking and EVA and, when these failed to materialize, instantly jumped to the conclusion that the mission was a failure and that the extensive mutual maneuvers were unsuccessful attempts at docking. X

At the same time, it should be remembered that the Soviets are very cost conscious about their space program, and that unlike Americans, they do not feel that they can afford to repeat missions already accomplished. The Soyuz-6, -7, and -8 mission appears to be a perfectly logical step in a sequence which began with the automatic docking of two unmanned vehicles (Kosmos-186 and Kosmos-188). This was followed by the rendezvous between Soyuz-3 (manned by Beregovoy) and the unmanned Soyuz-2. The next step was the manual docking between Soyuz-4 and Soyuz-5. Having accomplished docking of two manned spacecraft and effected a transfer of crews from one spacecraft to another, the Soviets see no advantage in repeating that experiment.

The present Soyuz-6, -7, and -8 mission, is the next step in the series leading to the construction of a large, permanent station (or platform) in orbit. All of the major objectives of this mission point to that: the important place occupied by the development of autonomous navigation and mutual manual maneuvering, the experiment with light signals for communication, the welding experiment, and even the extensive biomedical investigations.

That EVA was not intended is obvious from the announcement made as early as October 11, that the cosmonauts did not have space suits on board. It was also announced at that time that the Soyuz-6 did not have docking facilities. There is an implication in one of the Soviet announcements [37] that this may have been due to the fact that Soyuz-6 was loaded with extra experimental equipment (presumably they refer to the welding equipment). It was also stated that the Soyuz-6 had no automatic approach equipment [41]. At the same time, it is known that the Soyuz-7 and Soyuz-8 did have equipment for automatic approach [27]. It was this fact that caused some Western journalists to assume that docking was intended. They also assumed that Shatalov's flat statement during the press interview that docking was not part of the Soyuz-6, -7, and -8 mission,

Some attention should also be given to the fact that TASS announced that the program of the mission was completed, and then blithely continued to describe work which the cosmonauts continued to carry on after their program was supposedly completed. This has been interpreted to mean that part of the program had been scrubbed, but this can also be explained by the fact that manual maneuvers used up less fuel than had been calculated and that the cosmonauts received permission to continue maneuvering.

There is very little room for doubting that the extensive manual maneuvering and the development of autonomous navigation without help from ground stations are necessary for, and bring the Soviets closer to, the construction of orbital stations. That the Soviets intend to move in this direction and that this constitutes the primary goal of their manned space program is made very clear by responsible Soviet officials. Academician Keldysh made this perfectly clear when he explained that exploration of the moon and of the planets will be carried out with automatic equipment, and that they have no intention of sending a man to the moon in the immediate future.

Perhaps most interesting was Keldysh's statement that the ability of man to withstand weightless conditions for extended periods of time is the main obstacle standing in the way of creating a permanent station in orbit [35]. This statement carries an implication that from a purely technical or engineering point of view the station could be created much sooner. This may explain the rather extensive program of biomedical investigations carried out during the Soyuz-6, -7, and -8 mission. It may also explain the reason why all three spacecraft were in orbit for the same period of time (118 hours and 41 minutes from takeoff to touchdown). This mission should provide the Soviet biomedical specialists with an interesting amount of data on the physiological effects of spaceflight conditions on seven human organisms. Although this period of exposure to space is too short to provide complete physiological adaptation to weightlessness, it nevertheless will provide the Soviets with a far greater amount of data on man's exposure to space than they have had heretofore available to them.

Another point worth noticing about the coverage given to the present mission, is the amount of stress placed on the fact that the mission was not simply experimental, but an operational mission serving the needs of Soviet science and of Soviet national economy. In previous flights, the stress on this point was comparatively small. When such statements are made by specialists connected with the spaceflight program, they can be discounted as attempts to feather their own nests. However, throughout this entire flight not only specialists, but TASS itself, and even the leaders of the Soviet government repeatedly stressed the value of the current mission to the needs of Soviet science and to the fact that it serves the ends of national economy. This stress on the part of the leaders of the Soviet government and the Communist party of the USSR, indicates that they feel the need for rallying public support to the continuance of their space program. The reasons for the need for this stress at the present time are not clear. What is clear is that the Soviet government appears determined to push forward with their manned spaceflight program, and particularly with the program to construct a large station in terrestrial orbit, with all possible vigor.

REFERENCES

1. TASS. Pravda, 12 Oct 69, p. 1, cols. 1-2
2. TASS. Pravda, 12 Oct 69, p. 1, cols. 3-4
3. TASS. Pravda, 12 Oct 69, p. 1, cols. 5-6
4. TASS. Pravda, 13 Oct 69, p. 1, cols. 1-3
5. TASS. Pravda, 14 Oct 69, p. 1, cols. 4-5
6. TASS. Pravda, 14 Oct 69, p. 1, cols. 3-5 and p. 2, cols. 1-3
7. TASS. Pravda, 15 Oct 69, p. 1, cols. 1-3
8. Smirnov, V. Pravda, 15 Oct 69, p. 3, cols. 1-2
9. TASS. Pravda, 16 Oct 69, p. 1, cols. 1-3
10. Borzenko, S. Pravda, 16 Oct 69, p. 3, cols. 1-3
11. Smirnov, V. Pravda, 16 Oct 69, p. 3, cols. 5-7
12. TASS. Pravda, 17 Oct 69, p. 1, cols. 1-2
13. TASS. Pravda, 17 Oct 69, p. 1, cols. 4-5
14. Borzenko, S. and N. Laptev. Pravda, 17 Oct 69, p. 1, cols. 1-3
15. Smirnov, V. Pravda, 17 Oct 69, p. 3, cols. 1-5
16. Paton, B. Pravda, 17 Oct 69, p. 3, cols. 6-8
17. TASS. Izvestiya, 18 Oct 69, p. 1, cols. 4-5
18. TASS. Izvestiya, 18 Oct 69, p. 1, cols. 5-6
19. Gukasov, G. and G. Ostroumov. Izvestiya, 18 Oct 69, p. 1, cols. 1-6 and p. 2, cols. 1-5

20. Pavlov, L. et al. Izvestiya, 18 Oct 69, p. 2, cols. 1-3

21. TASS. Pravda, 19 Oct 69, p. 1, cols. 3-4

22. Central Committee of the CPSU et al. Pravda, 19 Oct 69, p. 1, cols. 3-4

23. TASS. Pravda, 19 Oct 69, p. 3, col. 7

24. Smirnov, V. Pravda, 19 Oct 69, p. 3, cols. 1-5

25. Borzenko, S. Pravda, 20 Oct 69, p. 3, cols. 2-5

26. Keldysh, M. V. Izvestiya, 5 Nov 69, p. 1, cols. 1-6

27. Shatalov, V. A. Izvestiya, 5 Nov 69, p. 1, cols. 5-7, and p. 4, cols. 1-2

28. Kubasov, V. N. Izvestiya, 5 Nov 69, p. 4, cols. 1-4

29. Shonin, G. S. Izvestiya, 5 Nov 69, p. 4, cols. 3-4

30. Filipchenko, A. V. Izvestiya, 5 Nov 69, p. 4, cols. 3-7

31. Gorbatko, V. V. Izvestiya, 5 Nov 69, p. 4, cols. 6-7

32. Volkov, V. N. Izvestiya, 5 Nov 69, p. 4, cols. 6-7

33. Yeliseyev, A. S. Izvestiya, 5 Nov 69, p. 5, cols. 1-4

34. TASS. Krasnaya Zvezda, 6 Nov 69, p. 5, cols. 3-5

35. TASS (Keldysh, M. V.). Krasnaya Zvezda, 6 Nov 69, p. 5, cols. 6-7

36. TASS, International Service in English, Moscow, 1358 GMT, 11 Oct 69

37. Fonarin, V. and Yu. Fokin. Domestic Service in Russian, Moscow, 1500 GMT, 11 Oct 69

38. Karitskiy, A. International Service, Moscow, 1603 GMT, 11 Oct 69

39. TASS, International Service in English, Moscow, 1315 GMT, 12 Oct 69,

40. TASS, International Service in English, Moscow, 1339 GMT, 12 Oct 69,

41. TASS, International Service in English, Moscow, 1538 GMT, 12 Oct 69

42. TASS, International Service in English, Moscow, 1510 GMT, 13 Oct 69,

43. Denisov, V. Service to South Asia, Moscow, 1500 GMT, 13 Oct 69.

44. Rebrov, M. Krasnaya Zvezda, 14 Oct 69, p. 2, cols. 3-6

45. Platonov, Yu. Komsomol'skaya Pravda, 16 Oct 69, p. 4, cols. 1-4

46. Tumanov, A. Sel'skaya Zhizn', 14 Oct 69, p. 3, cols. 1-6

47. Beregovoy, G. Komsomol'skaya Pravda, 16 Oct 69, p. 4, cols. 5-8

48. TASS. Krasnaya Zvezda, 17 Oct 69, p. 2, cols. 1-4

49. Kazakov, N. Krasnaya Zvezda, 17 Oct 69, p. 2, cols. 1-4

50. TASS. Krasnaya Zvezda, 23 Oct 69, p. 1, cols. 1-3 and p. 2, cols. 1-2

51. Shatalov, V. A. Krasnaya Zvezda, 23 Oct 69, p. 2, cols. 4-7

52. Shonin, G. S. Krasnaya Zvezda, 23 Oct 69, p. 2, cols. 5-7 and p. 3, cols. 1-3

53. Brezhnev, L. I. Krasnaya Zvezda, 23 Oct 69, p. 3, cols. 4-7